A Brief Introduction to Deployment Problem

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Outline

- Introduction
- Design tool
- Example
- Direction of research

Introduction

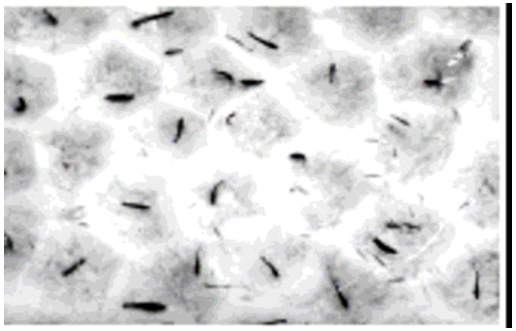
Multi-agent Systems : Each agent can

- Sense its environment
- Communicate with others
- Process the information
- Take a local action


School of fish

Motion Coordination :

- Rendezvous/Flocking : gather at a location /agreeing over the direction of motion.


Territorial behavior

- Deployment : Optimal coverage over a region

Application : Surveillance, environmental monitoring for pollution detection, etc

S. Martinez et al., IEEE Control Systems Magazine, 2007

Goal

Design coverage algorithms :

- Adaptive : changing env., network topology (agents failures, etc).
- Distributed : depend only on neighbors.
- Asynchronous : can be impelemented for agents evolving at diff. speeds, communication ability etc.
- Asymptotically correct.

Design/analysis tool :

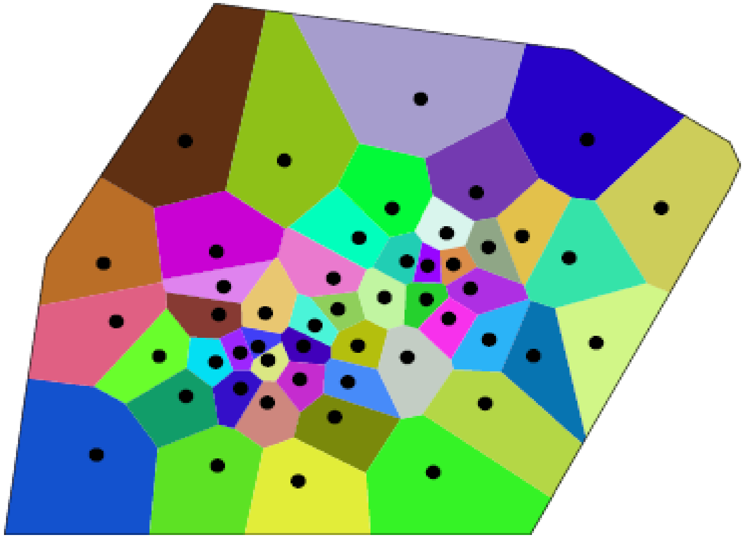
- Proximity graph : not fixed graph.
- Network objective function.
- Invariance, convergence theorem.

Voronoi Partition

Let $P = \{p_1, \ldots, p_n\} \in Q^n$ denotes the position of n points in the space.

Voronoi partition generate by P :

$$V_i = \{q \in Q \,|\, \|q - p_i\| \le \|q - p_j\|, \forall j \ne i\}$$



Network Objective Function

- Obj. func. to encode motion coordination objective.

  Different objective func. will result to different behavior

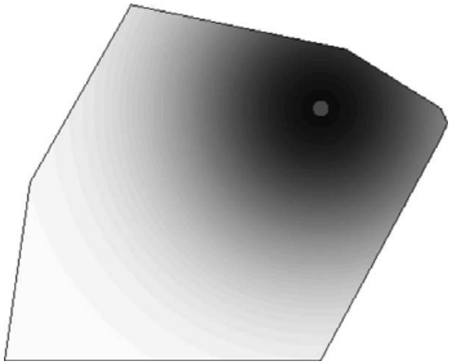
  Example : move-away-from-closest-neighbor

$$H(P)=\min_{i\neq j\in\{1,\ldots,n\}}\left\{\frac{1}{2}\left\|p_i-p_j\right\|,\mathrm{dist}\left(p_{i,}\partial Q\right)\right\}$$

- Obj. func. as Lyapunov function.
- Obj. func. for gradient flows : $u_i=-\dfrac{\partial H_v}{\partial p_i}$

Example: Distortion problem

- Objective : Given agents $(p_1,\ldots,p_n)$, convex environment Q, achieve optimal coverage.



- Let ϕ be density function
- Let f be sensing performance (non-decreasing)

  $f(\|q-p_i\|)$: how poor p_i to sense q

- Objective function :

$$H = \int_Q f(\|q - p_i\|)\phi(q)dq$$

$$= \sum_{i=!}^{n} \int_{w_i} f(\|q - p_i\|)\phi(q)dq$$

Cortes et al., IEEE Trans. Robotics and Automation

Distortion problem

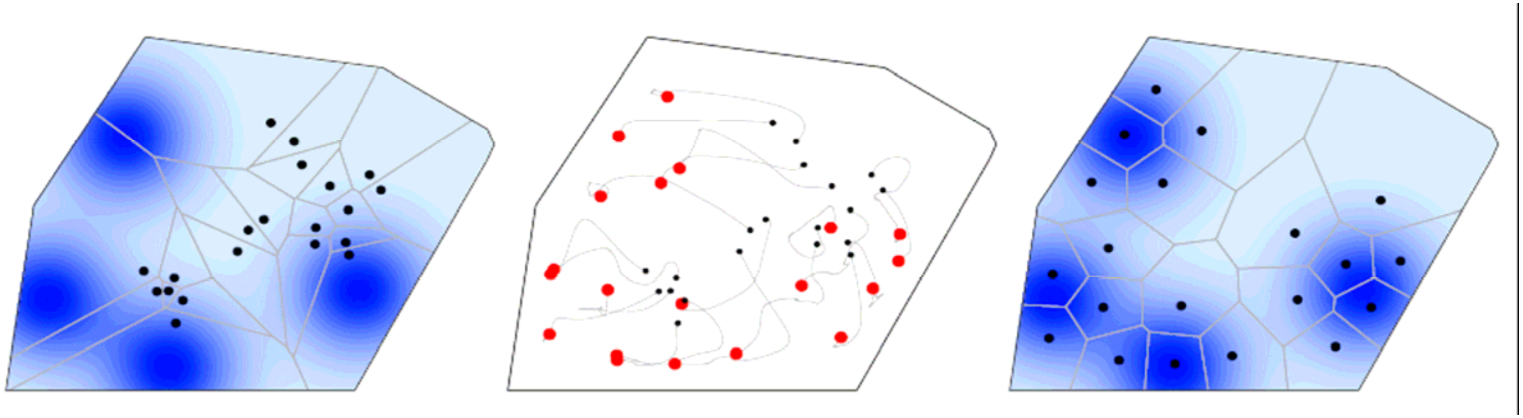
- At fixed sensor location, optimal partition : Voronoi partition

$$H(P)=\sum_{i=1}^{n}\int_{V_i} f(\|q-p_i\|)\phi(q)dq$$

- For $f(\|q-p_i\|)=\|q-p_i\|^2$ and dynamics $\dot{p}_i=u_i$,

$$u_i=-k\left(p_i-C_{V_i}\right)$$

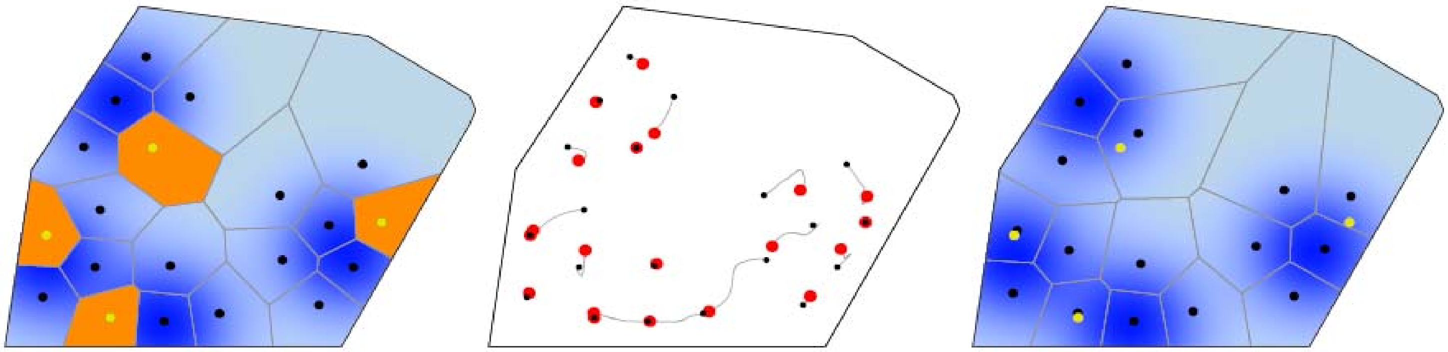
- Each sensor converges to centroidal voronoi



S. Martinez et al., IEEE Control Systems Magazine, 2007

Analysis

- Correctness : Gradient + Lasalle invariance principle
- Distributed : require only voronoi neighbors
- Adaptive : changing number of agents
- Asynchronous : determine own voronoi → determine central of voronoi → go to that direction



S. Martinez et al., IEEE Control Systems Magazine, 2007

References

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- Jorge Cortes, Sonia Martinez, Timur Karatas, Francesco Bullo, “Coverage Control for Mobile Sensing Network,” IEEE Transactions on Robotic and Automation, 2003